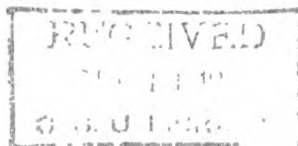


UNITED STATES BUREAU OF MINES
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**MILLING METHODS AND COSTS AT THE CONCENTRATOR
OF THE PREMIER GOLD MINING CO., LTD.,
PREMIER, B. C., CANADA**



BY

D. L. PITT, W. J. ASSELSTINE, AND D. L. COULTER

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INTRODUCTION

This paper, describing the milling methods at the concentrator of the Premier Gold Mining Co., Ltd., Premier, B. C., Canada, is one of a series being prepared by the United States Bureau of Mines on milling methods and costs in the various mining districts throughout the United States and Canada.

ACKNOWLEDGMENTS

The authors wish to acknowledge the assistance and suggestions given during the preparation of this paper by the engineering staff and accounting department of the Premier Gold Mining Co., Ltd., all of whom have assisted materially in gathering the data used.

LOCATION

The Premier mine and mill are situated in northern British Columbia, approximately 15 miles north of the head of the Portland Canal in the Salmon River section, about half a mile east of the Alaskan-British Columbia boundary line where it crosses the Salmon River. The mill is located on a rather steep hillside on the horizon of the main haulage level of the mine, and is within 100 feet of the mouth of the tunnel.

Both the mine and mill are connected with tidewater at Stewart, B. C., by an aerial tramway 11.5 miles long, which delivers both ore and concentrate to the bunkers at the dock for shipment to the smelters. All the mine and mill supplies except heavy machinery, are transported from Stewart dock to

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- 1 The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6742."
 - 2 One of the consulting engineers, U. S. Bureau of Mines, and manager, Premier Gold Mining Co., Ltd.
 - 3 Mill superintendent, Premier Gold Mining Co., Ltd.
 - 4 Assistant mill superintendent, Premier Gold Mining Co., Ltd.

Premier over this tramway. Heavy pieces are hauled either by truck in summer or sleighs in winter over a good road which runs from Stewart dock to Premier.

HISTORY

When the Premier mine first came to the attention of the public, in 1918, the impression was general that it was a bonanza deposit of straight shipping ore. While the first shipments were very high-grade gold-silver ore, it was early recognized by the management that in addition to the high grade there would be a considerable tonnage of milling ore. It was therefore necessary to look toward a milling program early in the mine's history.

The ore developed during the early stages of the mine's operation was a highly siliceous deposit carrying an intimate mixture of auriferous pyrite with small percentages of zinc, lead, and copper sulphides. The predominating values were in silver and gold.

Samples taken from development work and diamond-drill cores were sent to the Flat River, Mo., testing plant of the American Smelting & Refining Co., where tests were run to determine the best method of treating this type of ore. The wide variation in the composition and value of the ore is illustrated by the following analyses, representing various samples on which tests were run.

Table 1.- Variations in analyses of Premier ores

Assay No.	Assay, ounces per ton		Assay, percent					
	Gold	Silver	Lead	Zinc	Copper	Iron	Insoluble	Sulphur
1	0.024	14.2	0.20	....	0.015	3.6	91.1	1.65
2	.40	14.9	.15	....	.005	4.8	88.1	2.90
3	.41	5.2	2.45	....	.28	15.2	57.6	18.05
4	.64	20.6	.32	....	.025	6.8	80.7	2.85
5	1.26	28.6	.65	1.2	.....	6.3	80.3	6.50
6	1.33	42.9	.78	1.1	.....	6.1	77.3	6.30

The treatment methods used in testing comprised straight cyanidation and cyanidation in combination with tabling and flotation. The method adopted as a result of a great many tests, was to remove a fairly coarse table concentrate, high in gold; the table tailing was reground and treated by flotation for the removal of additional gold and silver, and the flotation tailing was thickened and treated by cyanide, using countercurrent decantation. This method differed from any other commercial installation then in use, and was distinctive in the feature that all grinding and flotation operations were done in cyanide solution. Flotation reagents used comprised: steam-distilled pine oil, Barrett No. 634 creosote oil, and coal tar. Wilfley tables and K&K flotation machines were used in concentrating. This treatment method was employed until 1926, with the results indicated in tables 2A and 2B.

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Table 2A.-- Weights and assays of mill products, 1923 to 1926

Year	Mill heads			Table concentrates			Flotation concentrates			Cyanide precipitates		
	Weight, dry tons	Assays, ounces per ton		Weight, dry tons	Assays, ounces per ton		Weight, dry tons	Assays, ounces per ton		Weight, dry tons	Assays, ounces per ton	
		Gold	Silver		Gold	Silver		Gold	Silver		Gold	Silver
1923	57.795	0.55	9.30	5.713	3.54	20.07	1.731	0.71	131.30	11.5795	726.66	9.118.7
1924	61.966	.54	10.40	6.427	3.30	23.59	2.148	1.48	111.26	13.642	510.80	8,674.7
1925	55.705	.47	8.30	2.539	6.27	26.19	3.713	1.55	82.44	6.4925	427.61	4,038.7
1926	122.152	.41	9.08	3.293	6.65	69.55	16.704	1.47	46.11	.....	.....	.....

Table 2B.-- Recoveries and concentration ratios, 1923 to 1926

Year	Recoveries, percent								Concentration ratios, percent of heads	
	Tables		Flotation		Cyanidation						Total
	Gold	Silver	Gold	Silver	Gold	Silver	Gold	Silver	Tables	Flotation
1923	65.42	20.04	3.86	39.73	26.46	18.44	95.74	78.21	9.88	3.00
1924	63.38	23.53	9.50	37.08	20.83	18.36	93.71	78.97	10.37	3.47
1925 1/	63.20	14.95	23.43	66.29	10.60	5.67	97.23	86.91	4.74	6.67
1926 2/	43.29	20.66	48.61	69.11	.....	.....	91.90	89.77	2.69	13.68
Average	.....	.....	.....	.....	.....	.....	94.48	84.55	.....	.....

1/ Cyanided for five months only.

2/ New 250-ton unit started in March.

In 1926 the development and use of chemical flotation reagents was receiving considerable attention and experiments with various combinations of these reagents were carried out in the mill laboratory. It was found that when xanthate and steam-distilled pine oil were used in a circuit made slightly alkaline with sodium carbonate, the recoveries by tabling and flotation equaled those formerly obtained by tabling, flotation, and cyanidation and at a considerable saving in cost. The results were so gratifying that a mill run of one month's duration was made using the experimental method and reagents as described. The results of the mill run were entirely satisfactory, and it was decided to discontinue cyanidation.

The original mill had a maximum daily capacity of 150 tons. When cyanidation was discontinued, another unit of 250 tons capacity was built. This increase of capacity was justified by additional milling ore that had been developed while opening up the mine.

The treatment methods employed for approximately one year after the completion of the new unit continued to be tabling followed by flotation. During this period experiments were carried on in the mill laboratory using various other combinations of chemicals and reagents. The results of these experiments indicated that all-flotation methods using aerofloat and sodium carbonate with a small amount of cyanide would give recoveries equally as good as were being made with flotation and tables and, therefore, in 1927, the tables were eliminated in the flow sheet and all-flotation methods adopted.

The kinds and quantities of flotation reagents used after the adoption of all-flotation methods from 1927 to 1931, inclusive, are given in table 3, and the metallurgical data for the same periods are presented in table 4.

In table 3 a decided decrease in the amount of sodium carbonate used may be noted, beginning in 1929, which was due to the adoption of hydrogen-ion control in the flotation circuit. The highest recoveries have been made when a pH value of 7.8 was maintained, although pH values greater than 7.8 have had neither detrimental nor beneficial results.

PRESENT METHOD OF MILLING

The ore is hauled to the mill by Edison storage-battery locomotives in trains of nine 2-ton-capacity cars. The main haulage system is on the fourth level of the mine and at the same elevation as the top of the mill bins. The ore was weighed in cars over a period of years and a weight factor determined for the cars. At present the mill tonnage is determined from the number of cars delivered, the weight factor for the cars being checked periodically. Moisture samples are taken, and over a period of years the ore has averaged 2 percent of moisture.

A side elevation of the concentrator is shown in figure 1.

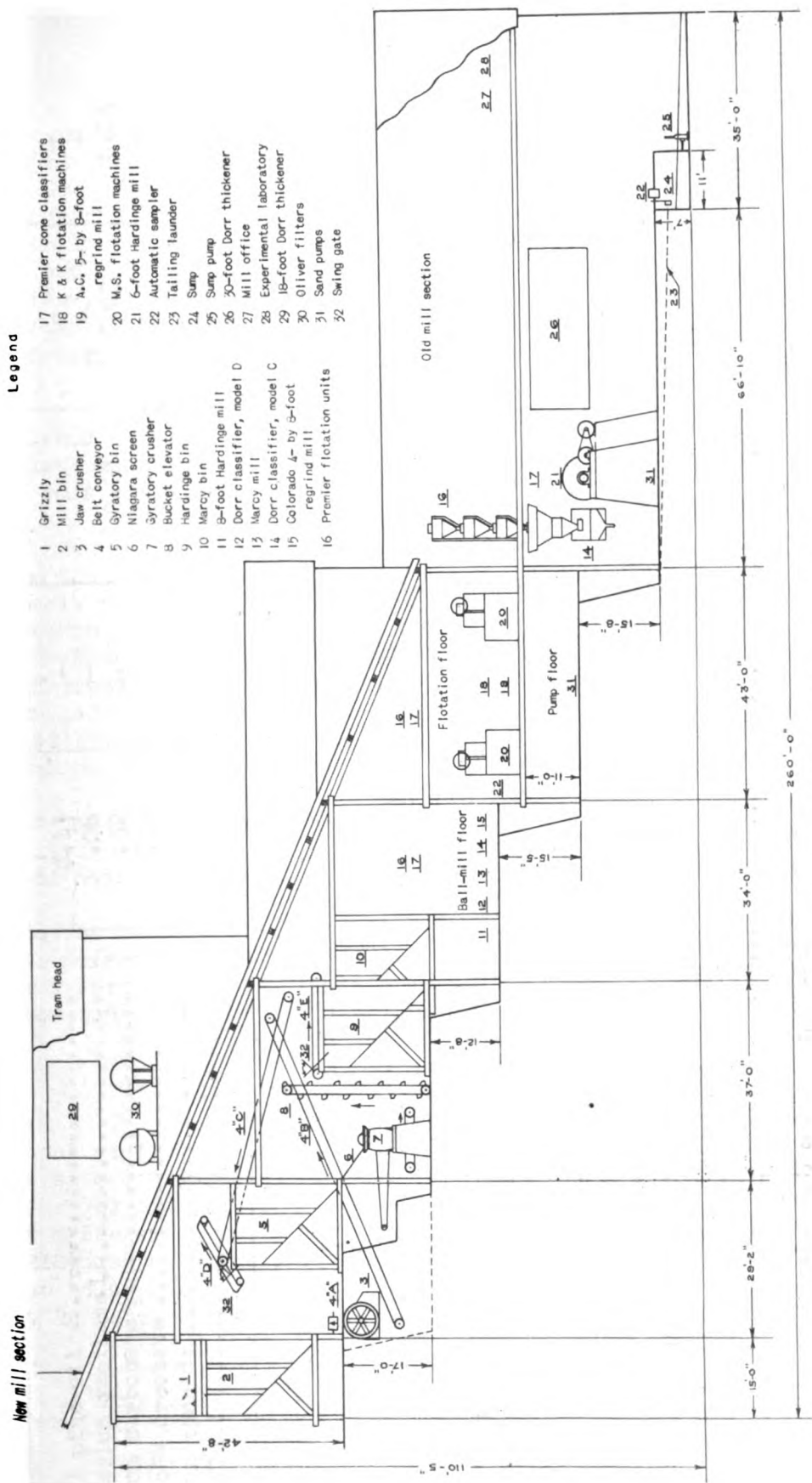


Figure 1.- Elevation with transverse section of Premier concentrator.

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Table 3.- Reagents used in all-flotation treatment

Reagent, pounds per ton milled		1927	1928	1929	1930	1931
No. 1 pine oil		0.13	-	-	-	-
Potassium xanthate		.06	-	-	-	-
Sodium carbonate		.52	0.40	0.08	0.02	0.03
No. 634 creosote		.13	-	-	-	-
Sodium cyanide		.07	.09	.07	.03	.01
Aerofloat		.26	.27	.27	.28	.27

Table 4.- Metallurgical data for years 1927 to 1931, inclusive

Year	Mill heads		Concentrates										Recoveries, percent		Concentration ratios, percent
	Weight, dry tons	Assays, ounces per ton	Weight, dry tons	Assays, ounces per ton		Analyses, percent									
				Gold	Silver	Gold	Silver	Lead	Zinc	Iron	Insoluble				
1927	147,536	0.39	7.17	1/1,701	5.27	21.89	3.7	5.4	37.0	6.6	15.41	3.51	1.15		
1928	162,112	.38	6.73	23,995	1.95	42.58	6.3	10.5	28.6	12.6	80.24	85.43	16.25		
1929	165,143	.30	6.38	17,062	3.47	53.46	8.1	12.1	21.2	20.7	95.30	84.04	10.52		
1930	151,936	.30	6.95	14,631	3.11	61.24	6.1	11.0	19.4	26.9	92.65	80.77	8.86		
1931	169,760	.305	5.93	15,681	2.71	62.19	4.3	8.1	23.7	26.8	93.37	92.34	10.32		
				20,116	2.41	43.17	3.3	8.7	26.0	20.7	93.35	86.29	11.85		

1/ Table concentrate produced during first 6 months.

CRUSHING

Referring to figure 2, mine-run of ore is dumped onto a grizzly made of 80-pound rails spaced 12 inches apart and thence into two bins, each of 100-ton capacity, one for high-grade ore and the other for mill ore. The high-grade ore is drawn from its bin onto a 26-inch, 12-ply belt conveyor, which carries it to an 18- by 30-inch Blake-type crusher set at 3 inches. The crushed product is then elevated by a system of three conveyors to the tramway ore bin, from which it is drawn into tram buckets and sent to the bunkers at the dock for shipment to smelters at either Tacoma or Anyox.

The mill ore is drawn from its bin onto a 42-inch Stephens-Adamson apron feeder and is fed directly to the same 18- by 30-inch jaw crusher that handles smelting ore. From the jaw crusher the ore is elevated by a series of two inclined conveyors, and discharged into a 100-ton-capacity bin. An electro-magnet is suspended over each conveyor for the removal of tramp steel and iron.

From the bin the Blake crusher product passes over a Niagara screen with 1-inch openings. The oversize is fed directly to a No. 6 McCully Superior gyratory crusher set at 1 inch. The material passing through the screen unites with the crusher discharge, then elevated by a 14- by 7-inch bucket elevator, and is discharged against an adjustable gate so set that about two-thirds of the product from the elevator goes into a bin above the Hardinge mill while the remainder is carried by a 20-inch conveyor to a bin above the Marcy mill.

In the original crushing installation there were two primary No. 3D Gates gyratory crushers, one for mill ore and the other to handle shipping ore. It was soon found, however, that the run-of-mine ore contained considerable amounts of material too coarse to be handled by these small crushers; hence, it was necessary to put in the 18 by 30 inch jaw crusher as best the contour of the hill and the mill location would permit. The No. 3D mill gyratory crusher remained in the circuit until the new mill unit was built in 1926, when a larger one--a No. 6 McCully--replaced it to serve both old and new mill units. To accommodate these changes, a series of belt conveyors had to be worked out and fitted in as best suited to the existing units.

The capacity of the two crushers used at present is influenced by the character and condition of the ore mined during different seasons of the year. The heavy run-off when snows melt in the spring and during the rainy season finds its way underground and at times makes the ore very wet and sticky, causing the plugging of the gyratory crusher in spite of the removal of fines before crushing, thereby limiting the amount of material crushed. During these seasons the discharge opening of the gyratory crusher is increased somewhat, resulting in a coarser feed to the grinding units.

Crushing-plant data are given in table 5 and screen analyses of crushing-plant products in table 6.

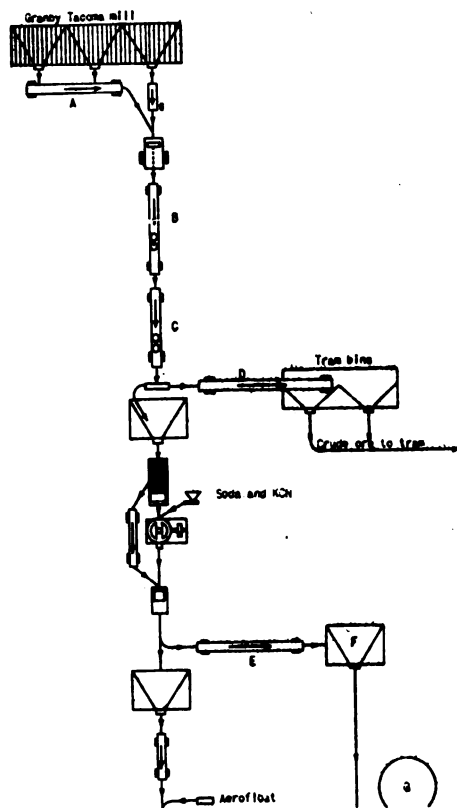


Figure 2.- Flow sheet of coarse and fine crushing.

- Legend
- Three mine bins, 100-ton capacity;
- A Belt conveyor, 26-inch, 10-hp. motor
 Apron feeder, 42-inch, 5-hp. motor
 Blake crusher, 30- by 10-inch, set at 3 inches, 50-hp. motor
- B Belt conveyor, 22-inch, 350 feet per minute, 10-hp. motor
 Suspended magnet
- C Belt conveyor, 22-inch, 350 feet per minute, 10-hp. motor
 Suspended magnet
 Deflecting gate - feed to tram or mill bins
- C Belt conveyor, 20-inch, 350 feet per minute to tram bin, 10-hp. motor
 Mill bin, 100-ton capacity
 No. 2 Niagara screen, 1-inch openings
 Dry reagent feeder for soda ash and cyanide
 No. 6 McCully gyratory crusher, 50-hp. motor
 Conveyor to elevator
- Bucket elevator, 14- by 7-inch buckets, 10-hp. motor
- E Belt conveyor, 20-inch, 250 feet per minute, 5-hp. motor
- F Bin feeding Marcy mill, 150-ton capacity
 Bin feeding Hardinge mill, 100-ton capacity
 Belt feeder, 20-inch, 6 feet per minute, 5-hp. motor
- G Water supply tank, constant head
 Mechanical reagent feeder

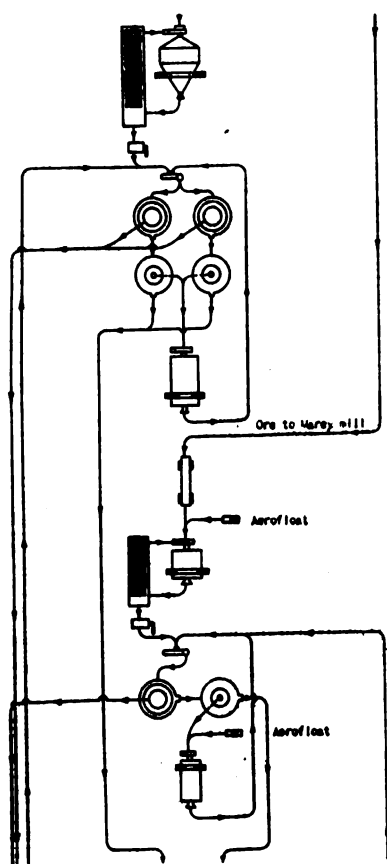


Figure 3.- Flow sheet of grinding and preliminary flotation.

- Hardinge ball mill, 6-foot by 5-inch 25 r.p.m., 150-hp. motor, Tex-rope drive
- Derr classifier, model D, 4- by 20-foot
- Ballinger automatic sampler
- Wilfley sand pump, 4-inch, 20-hp. motor
- Two Premier flotation cells
- Two Premier classifiers, 4-foot
- Colorado tube mill, 5- by 6-foot, 20 r.p.m., 75-hp. motor
- Belt feeder, 1 foot per minute
- Mechanical reagent feeder
- No. 6 1/2 Marcy ball mill, 25 r.p.m.¹
- Derr model C duplex classifier, 4 1/2-foot
- Ballinger automatic sampler
- Wilfley sand pump, 4-inch, 20-hp. motor
- Premier flotation cell
- Premier classifier, 4-foot
- Mechanical reagent feeder
- Colorado Iron Works tube mill, 4- by 6-foot, 30 r.p.m., belt driven
- ¹ A 200-hp. motor drives entire Marcy unit.

Table 5.- Crushing data for the year 1931

	Jaw crusher	Gyratory crusher
Size of feed openings.....inches ..	18 by 30	6
Size of discharge openings..... do. ...	3	1 1/4
Horsepower installed.....	50	60
Type of drive.....	Belt	Belt
Wear of stationary plates.....tons crushed	22,266	---
Wear of swing plates..... do. ...	39,516	---
Wear of set of concaves..... do. ...	---	39,868
Wear of mantle..... do. ...	---	106,386
Kind of wearing parts.....	Manganese steel	Manganese steel
Ore crushed per hour..... tons ...	42	22

Table 6.- Screen analyses of crushing-plant products, 1931

Size	Blake crusher ^{1/}		Gyratory crusher		Niagara screen undersize		Ball-mill feed	
	Per-cent	Cumulative	Per-cent	Cumulative	Per-cent	Cumulative	Per-cent	Cumulative
Plus 3 inch...	34.5	34.5	41.2	41.2	....	....	....	....
Plus 1 inch...	39.5	74.0	56.0	97.2	....	....	18.2	18.2
Plus 1/2 inch.	15.2	89.2	2/2.8	....	44.6	44.6	33.1	51.3
Plus 1/4 inch.	4.3	93.5	....	....	20.1	64.7	17.6	68.9
Minus 1/4 inch	6.5	....	....	....	35.3	....	31.1	....

^{1/} Feed all minus 12 inch.^{2/} Minus 1 inch.

GRINDING

The flow sheets of the newer and older grinding sections are presented in figure 3. In the newer unit the crushing-plant product is fed by a 20-inch conveyor to an 8-foot by 36-inch Hardinge ball mill operating in closed circuit with a Model D, 6- by 20-foot Dorr classifier. The overflow of the classifier is elevated by a 4-inch Wilfley sand pump to two 4 1/2-foot cones with 75° side slope placed in parallel and equipped with Premier flotation cells and sand discharge boxes. The two cones, with attachments, are in closed circuit with a 5- by 8-foot Allis-Chalmers tube mill.

In the older section of the mill, as shown in figure 3, the ore is fed by a 20-inch conveyor to a No. 64 1/2 Marcy ball mill operating in closed circuit with a 4-foot 6-inch by 14-foot 8-inch Model O Dorr classifier. The grate discharge of the ball mill has 1/8-inch openings. The classifier overflow is pumped to one 4 1/2-foot cone equipped with a Premier flotation cell and a sand-discharge box. The cone is operated in closed circuit with one 4- by 8-foot regrind mill.

The function of the flotation cells in both grinding circuits is to remove a coarse concentrate as soon as possible. The concentrates so removed from both circuits are sent by gravity to one 12-foot K&K cleaner flotation cell which produces finished concentrate for dewatering.

Data for primary and regrinding mills are presented in table 7; a typical screen analysis of feed to primary grinding mills is given in table 6 and screen analyses of primary grinding circuit products are presented in table 8; screen analyses of regrinding circuit products are presented in table 9. Consumption and costs of balls and liners are given in tables 10 and 11, respectively.

FLOTATION

The flotation flow sheet, except that part already described in the grinding circuits, is given in figure 5. The overflow from the cones of each grinding circuit passes to a set of three Premier flotation cells arranged in series. The concentrates from the six cells of the two sections are cleaned in one 12-foot K&K cell, which produces finished concentrate for dewatering. The tailing from the final cell of each section is sent to one 8-foot cone classifier. The discharge products of the two cone classifiers in both sections are sent to one 4 1/2-foot Dorr classifier. The Dorr classifier sand is delivered to one 6-foot by 16-inch Hardinge ball mill. The Dorr classifier overflow, together with the ball-mill discharge, is returned to the cone classifiers, thus closing the circuit between the cone classifiers and the grinding mill.

The overflows of the 8-foot cones are conveyed to a 4-foot surge box by a 4-inch Wilfley pump and from there are distributed partly to two 12-cell, 24-inch Minerals Separation subaeration machines placed in series, the remainder going to two double spitz, 12-foot K&K flotation machines placed in series. The concentrates from the first four cells of No. 1 Minerals Separation machines are finished products and are delivered to the concentrate collecting thickener by a 2-inch Wilfley pump. The froth products of the remaining 8 cells of this machine join those from the 12 cells of the second M. S. machine and are returned as middlings by a 2-inch Wilfley pump to both of the 4 1/2-foot cones above the regrind mills.

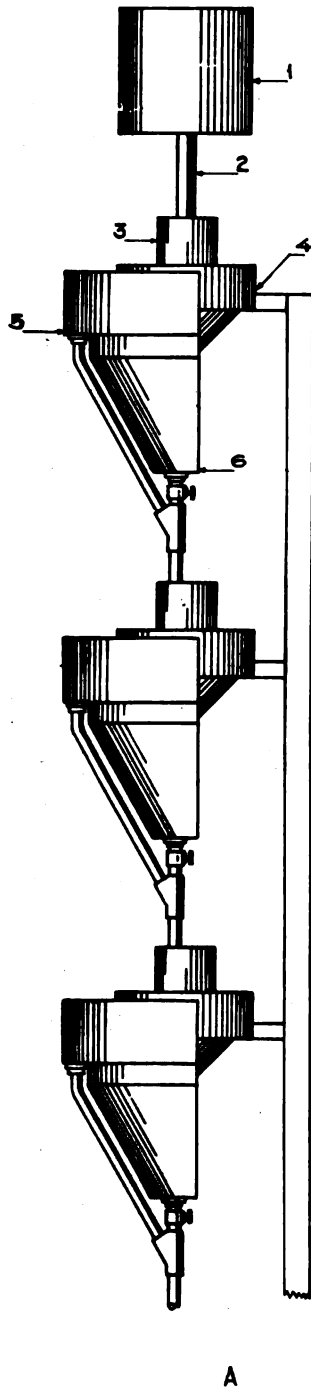
The concentrate from the first K&K rougher is cleaned in the K&K cleaner cell, which handles the rougher concentrates from the Premier cells. The froth from the second K&K rougher is returned to the 4 1/2-foot cones of the regrind circuit together with the middling froths of the Minerals Separation machines.

The tailing from the second K&K rougher and the tailing from the second Minerals Separation rougher are waste products.

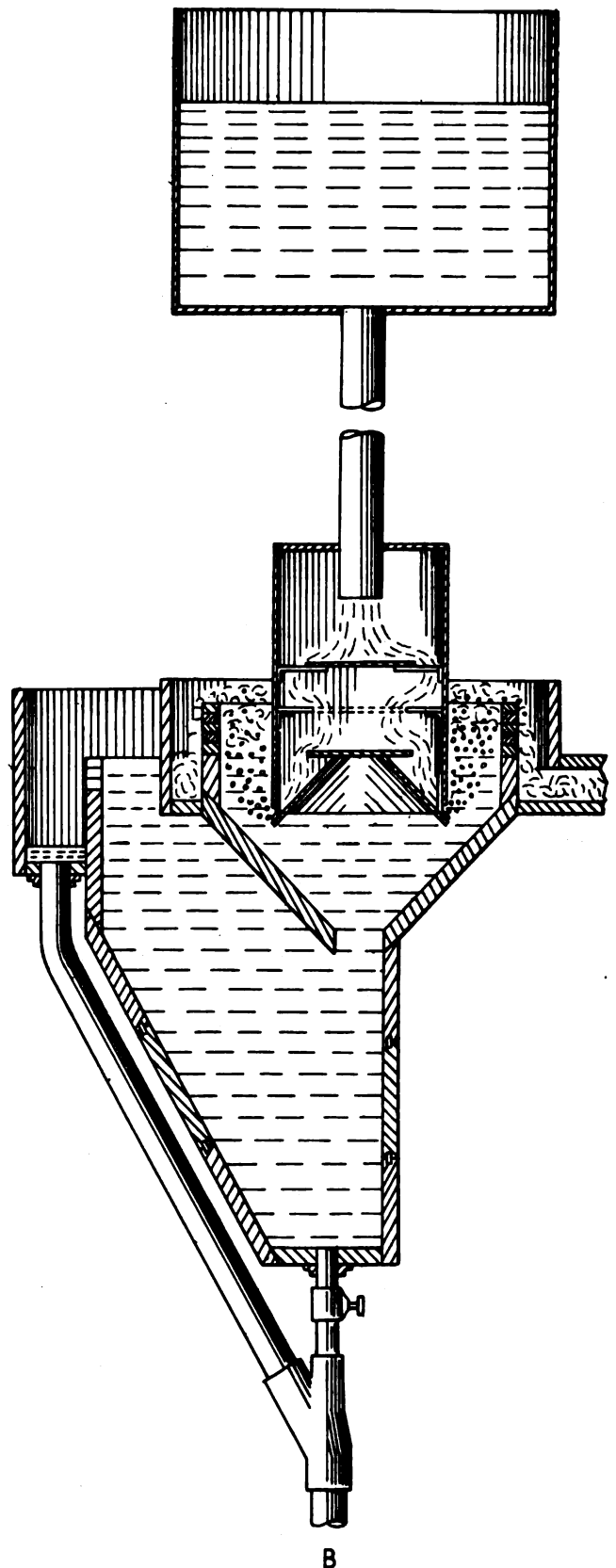
Aerofloat No. 15 is fed to all grinding units by mechanical feeders; cyanimid and soda ash are mixed dry and fed by a reconditioned Merrill zinc feeder to the ore at the gyratory crusher.

Legend

- 1 Feed tank
- 2 Feed pipe
- 3 Aerating chamber
- 4 Froth overflow
- 5 Fines overflow
- 6 Coarse discharge

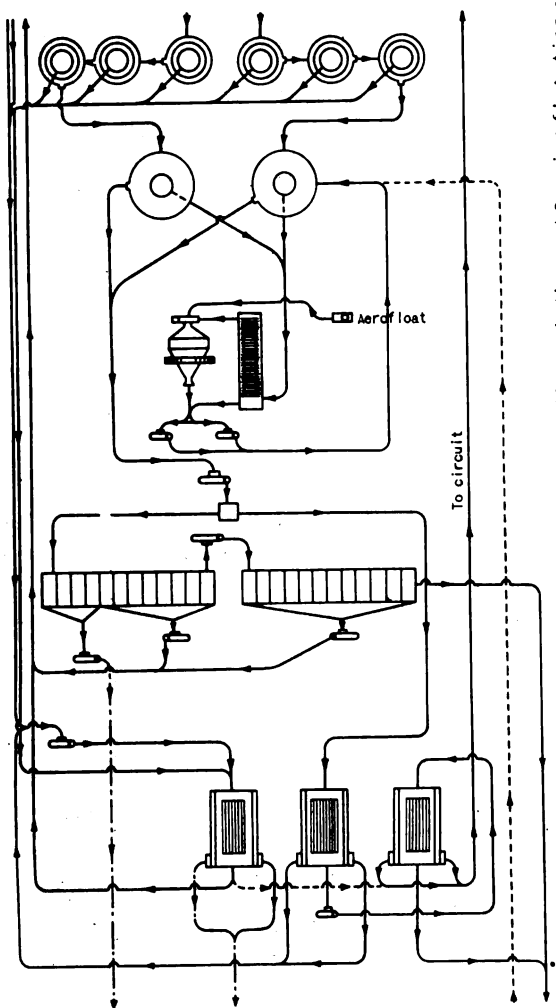


A



B

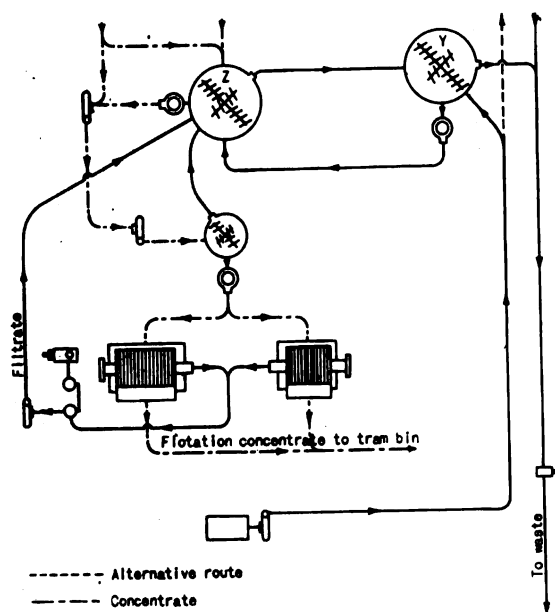
Figure 4.- A, Three-cell Premier flotation machine; B, details of Premier flotation cell



Fine grinding and Premier flotation cell

- Legend
- Six Premier flotation cells
 - Two cone classifiers
 - Mechanical reagent feeder
 - Hardinge ball mill, 6-foot by 16-inch, 27 r.p.m., 50-hp. motor, Tex-rope drive
 - Two Wilfley sand pumps, 2-inch, 10-hp. motors
 - Dorr duplex model C classifier
 - Wilfley sand pump, 4-inch, 20-hp. motor
 - Surge box, 4- by 4-foot
 - Wilfley sand pump, 4-inch, 20-hp. motor
 - Two M.S. sub A flotation machines, 12-cell, 24-inch, 75-hp. motor per machine
 - Two Wilfley sand pumps, 2-inch, 5-hp. motor
 - Wilfley sand pump, 2-inch, 5-hp. motor
 - Wilfley sand pump, 2-inch, 10-hp. motor
 - K & K cleaner flotation cell, 12-foot, double-spitz
 - Two K & K rougher flotation machines, 12-foot double-spitz
 - Wilfley sand pump, 2-inch, 10-hp. motor

Figure 5.- Flow sheet of flotation.



- Legend
- (V) Dorr thickener, 30-foot
 - Dorrco pump, No. 4
 - (Z) Dorr thickener, 30-foot
 - Wilfley sand pump, 3-inch, 25-hp. motor
 - Dorrco pump, No. 4
 - Wilfley sand pump, 2-inch, 15-hp. motor
 - Dorr thickener, 18-foot, equipped with 40-foot mechanism, 5-hp. motor
 - Dorrco pump, No. 4
 - Oliver filter, diameter 5 feet 4 inches, face 4 feet
 - Oliver filter, diameter 5 feet 4 inches, face 6 feet
 - Vacuum pumps, moisture trap
 - Dewatering pump
 - Gellinger automatic tailing sampler
 - Sump
 - Krogh sump pump, 3-inch, 15-hp. motor

Figure 6.- Flow sheet of dewatering.

Table 7.- Data for primary and regrinding mills

	Primary mills		Regrinding mills		
	Marcy	Hardinge	Denver Colorado mill	Allis-Chalmers bell granulator	Hardinge
Size: diameter and length.....feet.....	6 by 4 1/2	8 by 3	4 by 8	5 by 8	6 by 1.33
Speed.....r.p.m.	25	23	31	28	27
New feed per 24 hours..... tons ...	175	290	96	127	89
Total feed per 24 hours..... do. ...	350	510	233	414	208
Type of circuit	Closed	Closed	Closed	Closed	Closed
Installed horsepower.....	90	150	60	75	75
Method of driving.....	Clutch	Tex-rope	Belt	Flexible coupling	Tex-rope
Solids in mill pulps.....per cent....	79.3	76.8	76.0	75.5	76.5
Solids in classifier overflows..... do. ...	54.2	62.4	22.8	26.1	62.8
Type of feeder.....	Scoop	Comb. drum	Scoop	Scoop	Scoop
Ball load..... pounds ...	7,000	33,000	11,000	17,500	10,000
Liner material.....	Mn steel	Mn steel	Cast-iron	Cast-iron	Cast-iron
Liner consumption.....pounds per ton	0.40	0.38	0.14	0.08	0.04
Grate material.....	C.r. steel	.....	.....	.....	.....
Grate consumptions.....pounds per ton	0.07	.....	.....	.....	.....
Diameter of balls..... inches ...	5	5	2 1/2	2 1/2	1 3/4
Ball material.....	Forged steel	Forged steel	Cast-iron	Cast-iron	Forged steel
Ball consumption.....pounds per ton	1.94	2.39	1.34	1.33	0.61
Type classifier.....	Dorr duplex	Dorr duplex	Premier cone	Premier cone	Premier cone
Size of classifier.....feet.....	4.5 by 14.7	6 by 20	4 1/2	4 1/2	8 and 4 1/2 by 14.7
Speed of rakes per minute.....strokes...	27	27	.....	.....	18

Table 8.- Screen analyses of products of primary grinding circuits, 1931

Mesh	No. 64 1/2 Marcy						8-foot by 36-inch Hardinge					
	Ball-mill discharge		Classifier				Ball-mill discharge		Classifier			
			Return		Overflow				Return		Overflow	
	Per- cent	Cum.	Per- cent	Cum.	Per- cent	Cum.	Per- cent	Cum.	Per- cent	Cum.	Per- cent	Cum.
+20...	26.7	26.7	33.4	33.4	2.5	2.5	26.3	26.3	28.5	28.5	1.3	1.3
+50...	30.6	57.3	39.4	72.8	20.4	22.9	31.6	57.9	41.1	69.6	17.1	13.4
+80...	10.3	67.6	11.4	84.2	16.3	39.2	10.5	68.4	12.8	82.2	16.4	34.8
+100...	5.4	73.0	3.9	88.1	8.7	47.9	5.5	72.7	4.4	86.6	8.6	43.4
+150...	4.4	77.4	2.4	90.5	7.0	54.9	4.0	77.7	2.7	39.3	7.5	50.9
+200...	4.5	81.9	2.1	92.6	8.7	63.6	4.8	82.5	2.2	91.5	9.7	60.6
-200...	18.1	100.0	7.4	100.0	36.4	100.0	17.5	100.0	8.5	100.0	39.4	100.0

Table 9.- Screen analyses of regrinding circuit products, 1931

Screen size, mesh	Marcy-mill section, 4 1/2-foot cone classifier				4- by 8-foot regrind-mill discharge		Hardinge-mill section, 4 1/2-foot cone classifier				5- by 8-foot regrind-mill discharge	
	Discharge		Overflow		Per-cent	Cum.	Discharge		Overflow		Per-cent	Cum.
	Per-cent	Cum.	Per-cent	Cum.			Per-cent	Cum.	Per-cent	Cum.		
+50...	39.9	39.9	1.9	1.9	7.8	7.8	37.5	37.5	0.3	0.3	27.4	27.4
+80...	27.7	67.6	6.7	8.6	12.9	20.7	25.3	62.8	1.7	2.0	23.0	50.4
+100...	14.1	81.7	9.3	18.4	11.5	32.2	13.0	75.8	7.3	9.3	11.1	61.5
+150...	8.0	89.7	11.2	29.6	15.2	47.4	8.9	84.7	8.0	17.3	7.1	68.6
+200...	5.1	94.8	11.7	31.3	16.0	63.4	6.7	91.4	8.1	25.4	5.5	74.1
-200...	5.2	100.0	58.7	100.0	36.6	100.0	8.6	100.0	74.6	100.0	25.9	100.0

Screen size, mesh	8-foot cone classifier handling primary tailing				Dorr classifier in circuit with 6-foot Hardinge mill				6-foot Hardinge regrind-mill discharge	
	Discharge		Overflow		Return		Overflow		Per-cent	Cum.
	Per-cent	Cum.	Per-cent	Cum.	Per-cent	Cum.	Per-cent	Cum.		
+50...	13.5	13.5	0.3	0.3	13.1	13.1	0.9	0.9	6.0	6.0
+80...	23.7	37.2	2.2	2.5	38.1	51.2	12.1	13.0	10.1	16.1
+100...	19.7	56.9	7.7	10.2	23.5	74.7	19.9	32.9	10.8	26.9
+150...	15.6	72.5	9.8	20.0	12.4	87.1	21.5	54.4	11.7	38.6
+200...	13.1	85.6	12.1	32.1	6.2	93.3	13.6	68.0	12.5	51.1
-200...	14.4	100.0	67.9	100.0	6.7	100.0	32.0	100.0	48.9	100.0

Table 10.- Consumption and cost of balls used in grinding circuits, years 1927-1931, inclusive

Year	Ore milled, dry tons	Total steel balls used, pounds	Average unit cost of balls per 100 pounds	Total cost of balls	Balls consumed per ton of ore, pounds	Cost of balls per ton of ore treated
1927	147,536	595,635	\$3.76	\$23,061.47	4.03	\$0.156
1928	162,112	720,625	3.76	27,085.94	4.44	.167
1929	165,143	668,540	3.47	23,215.62	4.05	.141
1930	151,936	668,750	3.99	26,664.27	4.40	.175
1931	169,760	707,844	3.29	23,271.83	4.17	.137

Table 11.- Consumption and cost of ball mill liners, years 1927-1931, inclusive

Year	Ore milled, dry tons	Total cast-iron and steel liners used, pounds	Average unit cost of liners per 100 pounds	Total cost of liners	Pounds per ton milled	Liner cost per ton of ore milled
1927	147,536	94,340	\$13.30	\$12,531.74	0.639	\$0.085
1928	162,112	104,730	12.19	12,767.93	.646	.079
1929	165,143	93,289	11.02	10,278.12	.565	.062
1930	151,936	112,745	10.71	12,072.56	.742	.079
1931	169,730	89,286	10.32	9,218.54	.526	.054

The flow sheet as described employs a stage grinding-flotation-classification system, which gives a differential grinding effect whereby the heavier sulphide particles are ground much finer than the gangue material. The development of this flow sheet resulted from data obtained from mill operations and laboratory tests. It was found that 50 to 60 percent of the mineral values could be recovered when the ore was ground 50 percent minus 200 mesh, and that the balance could be removed as a middling product to be returned to the circuit for further classifying, grinding, and flotation. When the present method was adopted, the size of grinding was decreased from 81 percent minus 200 mesh to 70 percent minus 200 mesh without affecting either recoveries or grade of concentrate.

A 3-cell Premier flotation machine is shown in figure 4A, and the details of one cell are shown in figure 4B. This machine is of the cascade type and was developed for use between the primary grinding and regrinding circuits and in this position removes a concentrate as soon as grinding has reached the degree where flotation is possible. In addition to the advantage of permitting coarser grinding, the Premier flotation machine removes the valuable minerals from the circuit as soon as possible, eliminates the peaks in the feed to the mechanical flotation machines, and produces a coarse concentrate, which in turn improves thickening and filtering operations. Previous to the installation of those cells, when flotation feed was ground 81 percent minus 200 mesh, the thickening and filtering capacity was taxed to the limit in handling the finely ground concentrate. After the introduction of the stage grinding-flotation-classification system, the percent of minus 200-mesh material in the concentrate decreased from 88 to 60 percent and the capacity of the filters increased from 525 to 998 pounds per square foot per 24 hours.

Typical analyses of flotation products and typical recoveries of gold and silver are given in table 12; typical screen-assay analyses of final concentrate and tailing are given in table 13.

Table 12.- Typical analyses of flotation products and recoveries for August, 1932

	Weights			Analyses						Recoveries	
	Per- cent of total	Mois- ture, per- cent	Dry tons	Ounces per ton		Percent				Per- cent gold	Per- cent silver
				Gold	Silver	Lead	Zinc	Iron	Insol.		
Heads	100.0	2.0	12,782	0.35	6.55	0.7	1.7	6.0	74.2	.....	.....
Primary con- centrate from Premier cells .....	.....	.....	.....	2.48	34.00	2.4	7.7	23.5	10.8	.....	.....
K&K cleaned concentrate. ....	.....	.....	.....	2.92	51.12	2.7	8.8	27.3	13.0	.....	.....
Feed to sec- ondary flo- tation machines....	.....	.....	.....	.17	4.52	.2	1.9	5.1	79.5	.....	.....
M.S. Concen- trate .....	.....	.....	.....	2.80	60.50	3.1	10.5	29.8	7.6	.....	.....
Middlings ...	.....	.....	.....	.62	18.67	1.2	9.1	18.3	39.0	.....	.....
Final concen- trate	11.58	7.38	1,479	2.82	53.73	4.3	10.3	31.7	9.6	96.67	87.71
Final mill tailing	88.42	76.4	11,303	.013	0.91	.2	.6	2.6	82.6	3.33	12.29

Table 13.- Screen-assay analyses of final concentrate and tailing,
August, 1932

	Plus 150-mesh			Plus 200-mesh			Minus 200-mesh		
	Weight, per- cent	Assay, ounces per ton		Weight, per- cent	Assay, ounces per ton		Weight, per- cent	Assay, ounces per ton	
		Gold	Silver		Gold	Silver		Gold	Silver
Final con- centrate.	29.6	4.47	39.26	11.4	2.96	33.92	59.0	1.92	64.80
Tailing...	12.9	.021	.98	12.6	.022	.90	74.5	.013	.81

DEWATERING OF CONCENTRATE

Referring to the flow sheet of dewatering of concentrate given in figure 6, all concentrates are collected in one 30-foot Dorr thickener. The thickened pulp is delivered by a No. 4 Dorrco simplex pump to a pump feed box and from there it is elevated in two stages by 3-inch and 2-inch Wilfley pumps to an 18-foot thickener located above the tram terminal bins. Lime is used to aid settling and is added to the pulp at the rate of 0.3 pound per ton of concentrate.

The thickened pulp from the 18-foot thickener is delivered to either of two Oliver filters, 5 feet 4 inches by 6 feet or 5 feet 4 inches by 4 feet in size. The filters are so situated that the cakes, when discharging from the drums, drop into the concentrate bin and from there are drawn by gravity into buckets and conveyed by aerial tramway to the bunkers at the dock.

A flapping mechanism, shown in figure 7, is used to aid filtering. Before this mechanism was installed on the filters it was noted that a film of extremely fine material formed on the surface of the cake when the drum rotated through the pulp in the hopper, thus restricting the passage of air through the cake and retarding the removal of moisture. The use of the flapping mechanism broke this film and reduced moisture content from 11.3 to 10.0 percent. The production of coarse cleaned primary concentrate further reduced the moisture content from 10.0 to 8.3 percent. Filtering data are presented in table 14.

Table 14.- Filtering data

	Filter 1	Filter 2
Size, feet	5.33 by 4	5.33 by 6
Vacuum, inches of mercury at 1,400 feet elevation	21	21
Kind of cloth	Palma twill	Palma twill
Average life of cloth days.....	113	108
Average duty per 24 hours tons.....	31	45
Solids in feed pulp..... percent...	81.3	81.3
Moisture in cake..... do.	8.30	8.25

METALLURGICAL DATA

Metallurgical data for the year 1931 are given in table 15.

Table 15.- Metallurgical data, 1931

Assays of heads:		
Gold	ounces	0.305
Silver	do	5.93
Ore treated	tons	169,760.52
Days operated:		
Marcy unit		345.80
Hardinge unit		346.76
Operating time:		
Marcy unit	percent	95.00
Hardinge unit	do	95.26
Average ore milled per 24 hours:		
Marcy unit	tons	176.35
Hardinge unit	do	290.02
Total	do	466.37
Recovery of gold	percent	93.35
Recovery of silver	do	86.29
Concentration ratio, tons into 1		8.44
Moisture in concentrate	percent	8.28
Net water consumption per ton		
of ore milled	imperial gallons	700.
Ball consumption per ton of ore milled ..	pounds	4.17
Liner consumption per ton of ore milled ..	do	.526
Consumption of reagents per ton of ore milled:		
Aerofloat	pounds	.280
Sodium carbonate	do	.030
Cyanide (cyanamid)	do	.012

SAMPLING

The sample of mill heads is taken by Galigher automatic samplers which cut the overflow pulps of the primary classifiers at 7-minute intervals. An accurate sample of the ore actually milled is obtained by this method, as the grinding has been sufficiently fine to permit of accurate sampling.

The main tailing launder is equipped with a similar automatic sampler which takes the tailing sample, cutting the pulp stream at 7-minute intervals.

The grab samples of shipping concentrate are taken during the loading of each tramway bucket. Each bucket carries approximately 1,050 pounds. Over a period of years this method of sampling has yielded results which have checked smelter assays remarkably closely.

All intermediate concentrator products are sampled by hand.

All samples are for 24-hour periods and are collected at 10 p.m. Assay results from these samples are available the following day at 1:30 p.m.

EXPERIMENTAL LABORATORY

An experimental laboratory is maintained in connection with the milling operations.

WATER SUPPLY

The fresh-water supply is obtained entirely from the mine. The water flows from the upper mine workings to the mill supply tank. The mine water contains no substance injurious to flotation, and has a pH value of 7.2. The approximate yearly average temperature of this water is 36°.

LABOR

Few changes occur in the personnel of the operating crew, with the result that the men have become very familiar by observation with the changes in the ore passing through the plant. Operators are able to make necessary changes to take care of these fluctuations, in time to avoid disruptions in the circuits. Observations from panning various mill products or the use of "pilot" tables are not dependable as guides to flotation efficiency on Premier ore.

Milling operations are in charge of the mill superintendent, who is directly responsible to the management. The assistant superintendent is in charge of day-shift operations. A shift boss has charge of operations on afternoon and night shifts.

The repair crew is in charge of a repair foreman, who with two repairmen, take care of all routine repair work. One of the repairmen, who is an electrician, looks after minor electrical repairs and motor inspection. All major repairs are turned over to the mechanical department.

There are 25 men employed in the mill. Positions and rates of pay are listed in table 16.

Table 16.- Labor data

Position	Number of men	Rate per hour
Superintendent	1	Salary
Shift bosses	3	\$0.78
Jaw crusher	3	.50
Gyratory crusher	3	.48
Ball mill	3	.61
Flotation	3	.56
Filter	3	.56
Repair foreman	1	.78
Repairmen	2	.56
Laborers	1	.54
Conveyormen	1	.48
Testing department		Salary

SUPPLIES

Supplies are issued as required by the warehouse department upon requisitions signed by the mill superintendent. These requisitions, after passing through the warehouse, are checked daily by the management and returned to the mill superintendent.

On account of the distance from the source of supply for repair parts, reagents, etc., it is necessary to anticipate mill requirements from 1 to 3 months in advance.

CLIMATE

As the climate is comparatively mild, very little heating in the mill building is necessary. Owing to the occasional extremely heavy snowfall, however, very strong building construction is required.

Weather reports for the years 1925 to 1931, inclusive, are shown in table 17.

Table 17.- Weather reports, years 1925-1931

Year	Temperatures, °F.			Precipitation, inches	
	Maximum	Minimum	Mean	Snowfall	Rainfall
1925	36	-1.0	42.5	559	31.16
1926	82	1.0	41.0	434	51.63
1927	86	-6.0	37.0	555	30.00
1928	81.5	9.0	41.0	492	35.66
1929	78	0.0	41.0	345	46.00
1930	81	2.0	41.4	499	49.82
1931	85	4.0	41.0	433	48.27

POWER

All machinery is run by motors, power for which is supplied from the company's own plant. This plant is situated on Cascade Creek, half a mile below the mill. The plant consists of six Fairbanks-Morse Diesel engines with a total combined capacity of 1,680 hp.; one 3-runner, low-head Pelton wheel of 550 hp.; and two single-runner high-head Pelton wheels with a combined capacity of 550 hp.

During the summer months power is generated by the hydroelectric plant; and during the winter, owing to the lack of water, the Diesel engines are used. Power is generated and transmitted at 2,300 volts and is stepped down for some of the motors to 440, and for lighting to 110 volts.

A summary of power consumption and distribution for the year 1931 is presented in table 18.

Table 18.- Summary of power consumption for 1931
(169,760 tons of ore treated)

	Kilowatt-hours	Kilowatt-hours per ton	Percent of total power
Primary breaking	236,444	1.393	4.46
Secondary breaking	396,027	2.333	7.47
Primary grinding	1,211,681	7.138	22.84
Secondary grinding	572,008	5.726	18.32
Classification	76,562	.451	1.44
Flotation	1,038,584	6.118	19.58
Filtering	213,044	1.255	4.02
Pumps	991,980	5.843	18.70
Lighting	163,120	.990	3.17
Totals	5,304,450	31.247	100.00

COSTS

A summary of milling costs for the year 1931 is presented in table 19.

Table 19.- Summary of milling costs for 1931
(169,760 tons of ore treated; 48,389 ounces of gold
and 868,371 ounces of silver produced)

	Operat- ing labor	Power	Supplies	Repairs		Total
				Labor	Supplies	
Primary crushing	\$0.028	\$0.013	.....	\$0.024	\$0.027	\$0.092
Secondary crushing	.030	.019	.....	.008	.015	.070
Primary grinding .....	.....	.070	1/\$0.137	.026	.104	.337
Secondary grinding	1/.035	.055	.....	.010	.018	.118
Classifying .....	.....	.004	.....	.003	.003	.010
Flotation	.032	.050	.....	.020	.019	.121
Reagents .....	.....	.....	.059	.....	.....	.059
Filtering	.033	.010	.....	.004	.004	.051
Pumps, pipe lines, and launders .....	.....	.047	.....	.015	.030	.090
Oils, waste, and grease .....	.....	.....	.009	.....	.....	.009
Small tools .....	.....	.....	.002	.....	.....	.002
Motors, wiring, and lights .....	.....	.....	.....	.007	.006	.013
Lighting .....	.....	.006	.002	.....	.....	.008
Heating .....	.....	.....	.008	.....	.....	.008
Experimental	.009	.....	.....	.....	.....	.009
Building repairs .....	.....	.....	.....	.003	.003	.006
Superintendence	.064	.....	.....	.....	.....	.064
Total	0.231	0.274	0.217	0.118	0.227	1.067

1/ Primary grinding, secondary grinding, and classifying.

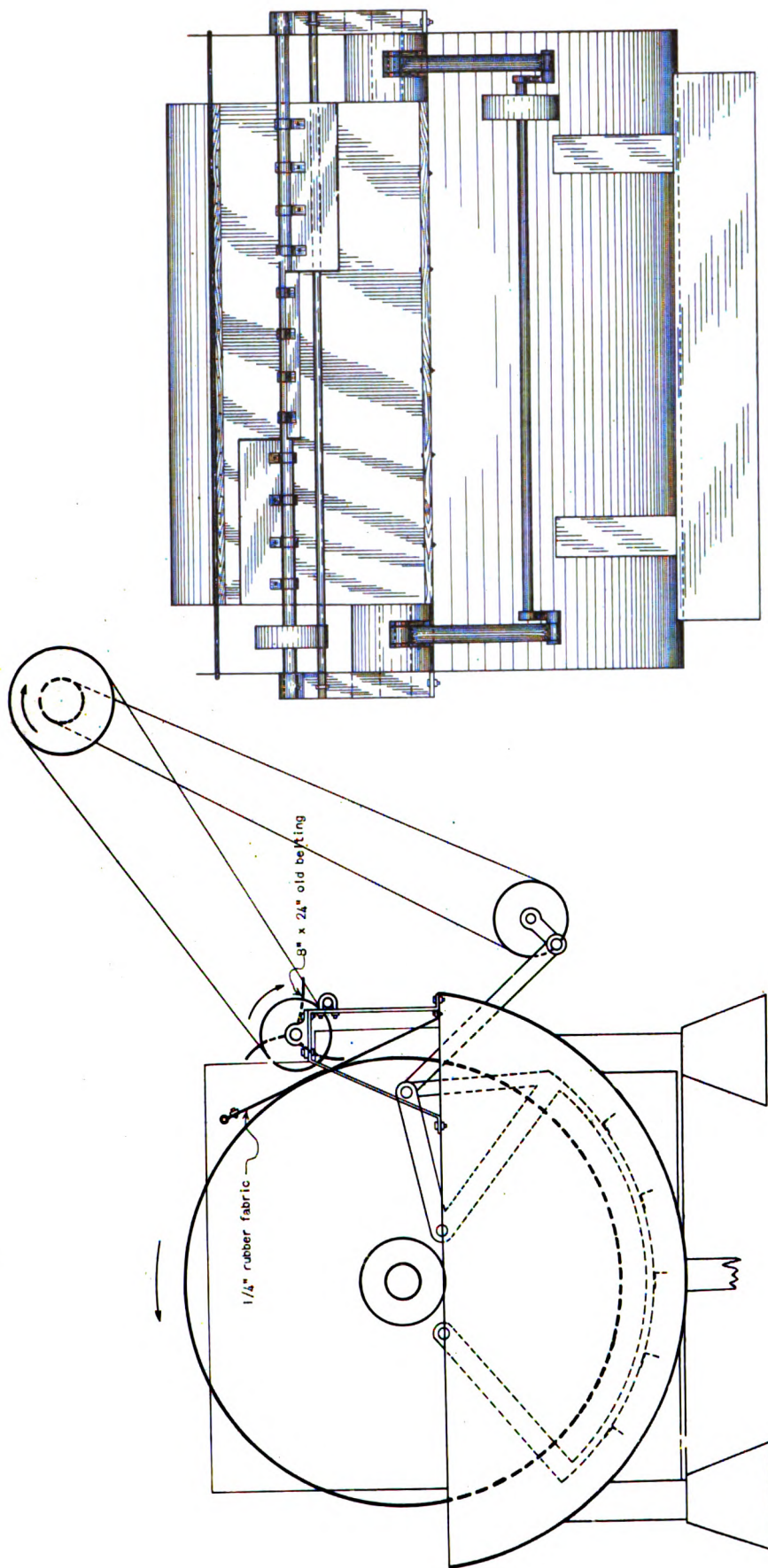


Figure 7.- General arrangement of Oliver filter, showing rubber flaps for breaking film on filter cake.